The contribution of shape features and demographic variables to disembedding abilities

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Abstract

Humans typically perceive visual patterns in a global manner, and are remarkably capable of extracting object shapes based on properties such as proximity, closure, symmetry, and good continuation. Notwithstanding people's attitude toward perceptual grouping, the research highlighted differences in disembedding performance across individuals, summarized by the field dependence/independence dimension. Previous studies revealed that age and educational attainment explain part of this variability, whereas the role of sex is still highly debated. Also, which stimulus features primarily influence inter-individual variations in perceptual grouping has to be fully determined.

Building upon these premises, we assessed the role of age, level of education and sex on performance at the Leuven-Embedded Figure Test - a proxy of disembedding abilities - in a sample of 391 cisgender individuals. We also investigated whether stimulus symmetry, closure, complexity, and continuation relate to task accuracy as a function of personal characteristics.

Overall, target asymmetry and continuation with the embedding context increase task difficulty, whereas target complexity demonstrates a U-shaped relationship with disembedding performance. Further, results unveil sex differences that have not been reported so far in adults and support the association between age, educational attainment, and disembedding abilities. Male individuals also benefit more from target symmetry and closure and are better at recognizing shapes when the embedding context is challenging. Lastly, highly educated adults better recognize asymmetrical and open targets, as well as shapes embedded in complex contexts. Taken together, our findings show how shape features relate to individual characteristics in explaining field independence.

Introduction

Human beings are equipped with a highly efficient visual processing system, which continuously extracts information from complex visual scenes. Along the visual pathway, each image is first decomposed in its essential features, and afterward, single elements are combined to prompt the emergence of a meaningful structure. Indeed, people are naturally prone to perceive in a global manner rather than in single units (*perceptual grouping*; Koffka, 1935; Brosnan et al., 2004), a disposition influenced by stimulus features such as *proximity*, *closure*, *symmetry*, and *good continuation* (Koffka, 1935; Herzog, 2018; see Wagemans et al., 2012a,b for a review).

Over the years, particular attention has been dedicated to understanding which individual differences affect the detection of single elements within the perceptual scene. In this regard, Witkin and colleagues developed the *Embedded Figure Test* (EFT) that requires the subject to spot simple shapes (i.e., *target*) within a more complex geometric pattern (i.e., *embedding context*; Witkin et al., 1950; 1971). Interestingly, despite the natural predisposition towards perceptual grouping, performance on this test showed substantial differences among individuals (Witkin et al., 1962; De-Wit et al., 2015).

According to Witkin and colleagues, such variability depends on the *field dependence/independence* dimension (FDI), originally defined as the ability to overcome an embedding context (Witkin et al., 1962; 1971). In this theoretical framework, field-dependent individuals are highly influenced by the visual context, whereas someone who is field-independent finds it easier to separate specific figure elements from their background. Over the years, Witkin's work and the EFT drew the attention of several researchers, prompting the study of individual differences in FDI in a variety of contexts, from education and learning performance (Goodenough, 1976; Sadler-Smith and Riding, 1999), to atypical development and autism

(Brosnan et al., 2004; Happé and Frith, 2006; Van Der Hallen et al., 2015). Previous works also investigated the relationship between disembedding abilities and demographic variables, such as age or sex. Specifically, there is a consensus for the increase of field dependence as a function of age (Lee and Pollack, 1978; Panek et al., 1980; Wiker et al., 2009; Chan and Yan, 2018), which is consistent with the overall decrease in performance on spatial tests observed in the elders (Techentin et al., 2014). Conversely, no significant sex differences were found in EFT performance (Signorella and Jamison, 1978; Linn and Petersen, 1985; Voyer et al., 1995), despite males scoring higher than females on other tests of spatial abilities (e.g., *Mental Rotation Tests*; Linn and Petersen, 1985; Voyer et al., 1995; Baron-Cohen, 2002; Uttal et al., 2013).

Moreover, several doubts concerning the nature of the FDI dimension have been raised (McKenna, 1984). Indeed, the EFT was either defined as a measure of maximum performance (i.e., a *non-verbal ability*) or a propensity (i.e., a *perceptual/cognitive style*). In Witkin's traditional theoretical framework, FDI is depicted as a preferred way to acquire, organize, manipulate and interpret information, namely a cognitive style (Witkin et al., 1962; Kozhevnikov, 2007). However, some authors criticized this interpretation, as cognitive styles should not be assessed using accuracy measurements (McKenna, 1984; Riding and Cheema, 1991; Zhang, 2004). Other authors emphasized the association between performance on the EFT and measures of attention, working memory, and intelligence, as well as a close relationship with learning outcomes and academic achievement (McKenna, 1984; Richardson and Turner, 2000; Evans et al., 2013; Danti et al., 2018). Though, to what extent these findings are consistent across studies is still highly debated (Huygelier et al., 2018) and, despite 60 years of research, the question about which perceptual features prompt individual differences in EFT performance remains unanswered (Milne and Szczerbinski, 2009; Chamberlain et al., 2017; Huygelier et al., 2018).

In this regard, De-Wit and colleagues developed a newer version of the EFT (*Leaven Embedded Figure Test*, L-EFT; De-Wit et al., 2017), in which features that may play a role in perceptual grouping have been intentionally manipulated. By measuring L-EFT performance in two different studies, the authors assessed how these perceptual properties affect embedding effectiveness, making the target more or less difficult to detect. They concluded that target shapes forming *good Gestalts* are easier to spot (e.g., symmetric targets), whereas good continuation between target shape and the embedding context increases task difficulty. However, it is worth noting that both experiments conducted by De-Wit and colleagues involved relatively homogeneous samples of undergraduate students with a majority of female individuals (i.e., 87% and 79% for experiments 1 and 2, respectively). This hampered the possibility to assess which personal characteristics are associated with disembedding performance.

Here, we aim to overcome this limitation by investigating the relationship between perceptual stimulus features and L-EFT accuracy in a more heterogeneous group of participants. Three hundred and ninety-one healthy Italian individuals were enrolled in this study, including a comparable number of cisgender men and women, with variable age and years of education. This sample allowed us to measure which stimulus features are processed differently by the two sexes, people of different age groups and education levels.

Materials and Methods

Participants

We recruited 391 participants among employees of a large banking group (255 F; mean age 39.5 years $\pm$ 6.2 standard deviation) from 97 out of the 107 Italian districts. There were no differences in age between male and female individuals (mean age for males: 39.8 $\pm$ 6.7 years; mean age for females: 39.3 $\pm$ 6.6 years; Wilcoxon Rank Sum test: z-score = 0.603; p-value = 0.546). Two-hundred and twenty individuals (56.3%) received high-school diplomas (13 years of education), whereas 171 (43.7%) got a university degree (minimum 16 years of education). There were no significant differences in the number of graduates between the sexes (114 university graduates among women; 57 among men; Chi-square test for independence: $X^2 = 0.281$; p-value = 0.596). Also, high school and university graduates did not differ in terms of age (mean age of high school graduate 39.8 $\pm$ 7.5; mean age of college graduate 39.1 $\pm$ 4.1).

Stimuli and Experimental Procedure

A 48-trial web-based version of the L-EFT (De-Wit et al., 2017) was employed in our study. In each trial, subjects had to detect a simple shape (i.e., *target*) embedded into a complex pattern of lines (i.e., *context*). Participants were asked to perform the task in a quiet environment free from distraction, to not take any break after starting the experiment and they were not timed. For each trial, the target was located in the upper and central part of the canvas, whereas three embedding contexts were presented simultaneously at the bottom of the screen (i.e., leftmost, central, and rightmost part of the canvas). The target shape embedded in the context preserved the same size and orientation as the one at the top of the screen. Only one of the complex figures at the bottom

contained the target shape, and its position was randomized across trials. Participants had to choose the context they believe incorporated the target by clicking on one proposed option. After providing their answer, they could not change their response to previous items. Target shapes may vary on three different parameters: *vertical symmetry* (i.e., symmetrical vs. asymmetrical figures), *closure* (i.e., open vs closed shapes), and the *number of lines* (i.e., 3, 4, 6, or 8 lines). Instead, embedding contexts varied according to the number of lines continuing those of the target shape (i.e., *number of continued lines*), ranging from 1 to the number of target lines. As compared with the original 64-item version of the L-EFT, we decided to not administer the 16 trials in which the number of continued lines was 0, as in De-Wit and colleagues (2017) these trials were recognized correctly by $96.6\% \pm 3.3\%$ of participants. Thus, by excluding these items we reduced completion time without sacrificing overall task difficulty.

Data analysis

Firstly, we investigated the relationship between stimulus properties (i.e., *vertical symmetry*, *closure*, *number of target lines*, *number of continued lines*) and disembedding performance. For each stimulus property, we estimated the number of subjects answering correctly to trials characterized by a specific feature. For instance, to evaluate to what extent target *closure* impacts participants' performance, we compared the number of correct answers for closed shapes with the accuracy for open targets. We assessed the statistical significance of these differences using nonparametric tests and significance level of $\alpha = 0.05$. Specifically, we used the Wilcoxon Rank Sum test for dichotomous variables, namely *symmetry*, and *closure*, and the Kruskal-Wallis test for multi-level variables (i.e., *number of target lines* and *number of continued lines*). Also, we

performed post-hoc analyses using the Wilcoxon Rank Sum test ($\alpha = 0.05$) and adjusted the significance threshold for the number of comparisons using the Bonferroni method.

Secondly, to assess the significance of demographic variables on disembedding performance, we measured the overall L-EFT accuracy for each subject as the ratio of the number of correct answers with respect to the number of trials. Forward stepwise regression analysis and the Bayesian Information Criterion (BIC) were employed to identify the best model explaining task accuracy, based on *age*, *sex*, *level of education*, as well as their interactions. For the optimal model, we estimated the full model fitting (F statistic; p-value), the explained variance (R-squared), and the statistical significance of single predictors (i.e., regressors β and related p-values). Results were then confirmed using nonparametric statistics: the Wilcoxon Rank Sum test for *sex* and *level of education*, and the Spearman correlation test for *age*.

Lastly, we evaluated how stimulus properties influenced task performance as function of sex, age, and education level. To this aim, we built specific linear regression models for each stimulus feature of interest (i.e., *symmetrical*, *asymmetrical*, *closed and open targets*; *three-, four-, six- and eight-line targets*; *minimum, intermediate and maximum number of continued lines*) using subjects' performance as dependent variable and demographic characteristics as predictors. For instance, to investigate how disembedding performance for closed targets changes as function of age, sex, and education level, we first estimated participants' accuracy at closed target trials only (i.e., 24 out of 48), and then employed the forward stepwise regression approach and the BIC to identify the optimal model. Similarly to previous analyses, full model fitting, explained variance and significance of individual predictors were estimated. All statistical analyses were implemented and performed in Matlab version 2018b (MathWorks Inc., Natick, MA, USA).

Results

Overall, participants exhibited a high accuracy in completing the L-EFT ($91.89\% \pm 5.87\%$). We did not find significant differences in accuracy between closed and open stimuli (Figure 1A; Wilcoxon Rank Sum Test: z-score = -0.01; p-value = 0.9917), whereas symmetrical targets were on average more easily recognized than asymmetrical ones (Figure 1B; Wilcoxon Rank Sum Test: z-score = -8.48; p-value = 2.24×10^{-17}). A significant main effect for the number of target lines was also highlighted (Kruskal–Wallis One-way Analysis of Variance: $X^2 = 86.84$; p-value = 1.05×10^{-18} ; Figure 1C): targets with three lines are identified more easily than those with four (Wilcoxon Rank Sum Test post-hoc: z-score = 9.04; Bonferroni adjusted p-value = 9.47×10^{-19}), six (z-score = 7.07; Bonferroni adjusted p-value = 9.06×10^{-12}) and eight (z-score = 4.84; Bonferroni adjusted p-value = 7.75×10^{-6}). In addition, participants showed a higher accuracy for eight-line targets as compared to four-line figures (z-score = -3.83; Bonferroni adjusted p-value = 7.69×10^{-4}). No other significant post-hoc tests were found after adjusting the significance level with the Bonferroni correction.

Figure 1 summarizes the relationship between stimulus properties and task difficulty. Panel **A** shows no significant differences between open (red) and closed (purple) targets. Dots represent participants' median performance $\pm$

interquartile range. Panel **B** depicts the significant effect of symmetry. Dots represent participants' median performance $\pm$ interquartile range. Panel **C** summarizes the association between the number of continued lines, shape complexity (i.e., 3-Line Target: blue; 4-Line Target: green; 6-Line Target: red; 8-Line Target: orange) and disembedding performance. Dots represent participants' average performance ($\pm$ standard deviation).

Results also showed a significant main effect for the number of continued lines (Kruskal–Wallis One-way Analysis of Variance: $X^2 = 375.64$; $p\text{-value} = 2.70 \times 10^{-82}$; Figure 1C): the higher the number of continued lines, the lower the recognition performance (min vs mid: $z\text{-score} = 8.05$; Bonferroni adjusted $p\text{-value} = 2.49 \times 10^{-15}$; min vs max: $z\text{-score} = 18.05$; Bonferroni adjusted $p\text{-value} = 2.15 \times 10^{-72}$; mid vs max: $z\text{-score} = 13.07$; Bonferroni adjusted $p\text{-value} = 1.39 \times 10^{-38}$).

When assessing the role of demographic variables on overall disembedding performance, the stepwise linear regression identified three significant predictors: sex, age and education level (age BIC = 2480.47; education BIC = 2478.11; sex BIC = 2478.05). This three-predictor model fits participants accuracy better than the intercept-only model ($F\text{-value} = 13.4$, $p\text{-value} = 2.46 \times 10^{-8}$) and explains 9.4% of the variance. Of note, no interaction terms were added to the model by the forward stepwise regression algorithm. When investigating the significance of single predictors, males were found to perform significantly better than females (Accuracy Males: $92.74\% \pm 5.55\%$; Accuracy Females: $91.44\% \pm 6.00\%$. β sex = 1.462 [Confidence Interval 90%: 0.29 - 2.635]; $t\text{-value}_{(1,387)} = 2.452$; $p\text{-value} = 0.0146$; Wilcoxon Rank Sum test: $z\text{-score} = 2.03$; $p\text{-value} = 0.0429$), whereas people with a high school diploma were less accurate than those with a university degree (accuracy in individuals with diploma: $91.10\% \pm 5.92\%$; accuracy in individuals with university degree $92.91\% \pm 5.66\%$. β education = 1.702 [CI 90%: 0.575, 2.828]; $t\text{-value}_{(1,387)} = 2.971$; $p\text{-value} = 0.0032$; Wilcoxon Rank Sum test: $z\text{-score} = -2.51$; $p\text{-value} = 0.0119$; Figure 2A-B). In addition, data showed that age was inversely related to disembedding accuracy: aging by a year was

associated with a reduction of 0.23% in L-EFT accuracy (β age = -0.228 [CI 90%: -0.318, -0.138]; $t\text{-value}_{(1,387)} = -5.001$, $p\text{-value} = 8.66 \times 10^{-7}$; Spearman Correlation test: $\rho = -0.203$; $p\text{-value} = 5.37 \times 10^{-5}$; Figure 2C).

Figure 2 shows the relationship between participants' characteristics and task performance. Panel **A** demonstrates the significant difference between males (light blue) and females (red) in disembedding abilities. Panel **B** depicts the advantage of college graduates (yellow) in the L-EFT. Panel **C** summarizes the negative correlation between age and field independence. Dots represent median performance $\pm$ interquartile range.

As a final step, we investigated which stimulus properties impact recognition abilities as a function of sex, age and education level. Findings showed that younger participants are better at detecting target stimuli regardless of *target closure*, *symmetry*, *number of target lines* and *number of continued lines* (Table 1).

	β	CI 90%	$t\text{-value}_{(1,387)}$	p-value
Closed	-0.055	-0.081, -0.028	-3.996	7.71×10^{-5}
Open	-0.055	-0.080, -0.030	-4.272	2.44×10^{-5}

Symmetrical	-0.046	-0.067, -0.026	-4.418	$1.30*10^{-5}$
Asymmetrical	-0.063	-0.094, -0.033	-4.093	$5.19*10^{-5}$
Three lines	-0.014	-0.026, -0.001	-2.150	0.0322
Four lines	-0.025	-0.042, -0.009	-3.000	0.0029
Six lines	-0.036	-0.053, -0.018	-4.063	$5.86*10^{-5}$
Eight lines	-0.035	-0.052, -0.017	-3.872	$1.27*10^{-4}$
Min continued	-0.015	-0.025, -0.005	-2.816	0.0051
Mid continued	-0.022	-0.039, -0.005	-2.575	0.0104
Max continued	-0.072	-0.103, -0.042	-4.659	$4.38*10^{-6}$

Table 1 summarizes the relationship between age and disembedding performance as a function of stimulus properties.

Moreover, we found that symmetrical and closed targets are recognized significantly better by male individuals as compared to female participants (symmetrical targets: $\beta = 0.343$ [CI 90%: 0.075, 0.612], $t\text{-value}_{(1,387)} = 2.512$; $p\text{-value} = 0.0124$; closed targets: $\beta = 0.421$ [CI 90%: 0.070, 0.772], $t\text{-value}_{(1,387)} = 2.358$; $p\text{-value} = 0.0188$). In addition, asymmetrical and open targets are better identified by people with a higher level of education (asymmetrical targets: $\beta = 0.734$ [CI 90%: 0.353, 1.116], $t\text{-value}_{(1,387)} = 3.784$; $p\text{-value} = 1.79*10^{-4}$; open targets: $\beta = 0.489$ [CI 90%: 0.172, 0.806], $t\text{-value}_{(1,387)} = 3.030$; $p\text{-value} = 0.0026$).

Years of education also predicted disembedding performances when the number of continued lines was maximum ($\beta = 0.571$ [CI 90%: 0.188, 0.954], $t\text{-value}_{(1,387)} = 2.930$; $p\text{-value} = 0.0036$) and intermediate ($\beta = 0.221$ [CI 90%: 0.007, 0.436], $t\text{-value}_{(1,387)} = 2.030$; $p\text{-value} = 0.0430$). Sex was associated with task accuracy in the more difficult condition of continued lines only ($\beta = 0.563$ [CI

90%: 0.164, 0.962], $t\text{-value}_{(1,387)} = 2.777$; $p\text{-value} = 0.0057$). Lastly, sex and education also played a role in disembedding performance depending on the number of target lines. Indeed, male participants scored significantly higher than females in trials with three- and six-line targets (three target lines: $\beta = 0.198$ [CI 90%: 0.034, 0.362], $t\text{-value}_{(1,387)} = 2.369$; $p\text{-value} = 0.0183$; six target lines: $\beta = 0.326$ [CI 90%: 0.101, 0.552], $t\text{-value}_{(1,387)} = 2.842$; $p\text{-value} = 0.0047$). College graduates performed significantly better than individuals with a high-school diploma when the target shape comprised four lines ($\beta = 0.392$ [CI 90%: 0.185, 0.601], $t\text{-value}_{(1,387)} = 3.711$; $p\text{-value} = 0.0002$).

Discussion

In the current study, we investigated how stimulus properties influence people's ability to detect simple shapes embedded within complex patterns of lines. A shortened version of the *Leuven Embedded Figure Test* (L-EFT; De-Wit et al., 2017) was used to assess disembedding performance in a sample of healthy Italian individuals, including a comparable number of cisgender males and females, as well as people of different age groups and education levels.

Our results show that target symmetry and the number of target lines affect disembedding performance. Specifically, vertical symmetry increases task accuracy, whereas the number of target lines shows a U-shaped relationship with disembedding performance: three- and eight-line shapes are easier to detect than four- and six-line targets. As for embedding context properties, the higher the number of continued lines is, the worse is recognition performance. Furthermore, we demonstrate that aging is associated with a reduction in disembedding performance and that males perform significantly better than females. Indeed, male individuals benefit more from target symmetry and closure and are better at recognizing target shapes when the embedding context is particularly challenging. Lastly, asymmetrical and open targets, as well as shapes embedded in complex contexts are more easily recognized by individuals with a higher education level.

In everyday life, the human visual system continuously organizes disjoint visual inputs into coherent patterns of information that we eventually identify as meaningful objects. This natural predisposition toward perceptual grouping is influenced by a set of stimulus features, such as *symmetry, closure, complexity, and good continuation*.

At the beginning of the 20th century, symmetry was described as one of the key grouping principles. When observing a visual scene, elements sharing a symmetric relation tend to be aggregated and perceived as a single figure standing out from the background (Koffka, 1935;

Bahnsen, 1928; Machilsen et al., 2009). Symmetry is an extremely salient visual property, as it is a prominent feature in the visual world (e.g., the majority of animals and plants exhibit bilateral symmetry) and a crucial factor for physical attractiveness and mate selection (Rhodes et al., 1998; Hume and Montgomerie, 2001; see Wade, 2010 for a review). According to psychophysical studies, symmetry detection occurs rapidly during pre-attentive stages of perception and does not require a conscious cognitive effort (Treder, 2010; Apthorp and Bell, 2015). Symmetrical shapes are also identified more accurately than asymmetrical figures (Carmody et al., 1977; Machilsen, et al., 2009; Pramod and Arun, 2018) and are easier to recall (Attneave, 1955; Kayaert and Wagemans, 2009). Our results extend the advantage of symmetrical shapes to disembedding tasks, as individuals detected more accurately symmetrical targets than asymmetrical ones. In the L-EFT all the symmetrical target shapes were characterized by vertical symmetry, which may have enhanced the magnitude of the detection advantage in disembedding performance. Indeed, previous studies showed that vertical symmetry is detected more easily than symmetry along other orientations (e.g., *horizontal symmetry*; Wagemans, 1995; Wenderoth, 1994; Evans et al., 2000). As for symmetry, Gestalt psychologists emphasized the role of closure in perceptual grouping and figure-background segmentation. During the early stages of perception, our visual system automatically groups elements enclosed by a continuous contour, as they are likely to belong to the same physical object. Closure plays an essential role in shape perception and objects recognition, which are, in turn, critical for building a coherent picture of the external world (Garrigan, 2012). Using a set of visual search experiments, Elder and Zucker (1993) empirically validated the function of closure in bridging 1D closed contours to 2D figures, which represented the boundaries of real-world objects projected onto the retina. Although, several studies found a perceptual advantage in closed contours detection (Elder and Zucker, 1993; Kimchi, 2000; Mathes

and Fahle, 2007; Gerhardstein et al., 2012; Garrigan, 2012), additional features, such as *element spacing*, *number of turning points*, or *lines length* might have confounded results relative to *closure* (Braun, 1999; Pettet et al., 1998; Tversky et al., 2004). For instance, Tversky and colleagues (2004) found only a modest advantage for closed shapes and argued that the facilitation introduced by contour detection could be attributed to the local application of other Gestalt principles (i.e., *good continuation* and *proximity*). More recently, De-Wit and colleagues investigated disembedding performance at the L-EFT for closed and open target shapes. Across two experiments, they found no differences in closure detection or even higher accuracy for open compared to closed shapes (De-Wit et al., 2017). Similarly, our findings support the absence of the perceptual advantage for closed shapes in disembedding tasks.

In our study, we also focused on the complexity of the target shape. Over the years, complexity was recognized as one important stimulus property affecting subjects' performance on a broad range of visual tasks. On the one hand, previous works reported that simplicity enhances shape processing, leading to better performances in delayed shape recognition for 2D figures (Kayaert and Wagemans, 2009), in mental rotation tests (Hall and Friedman, 1994), in simultaneous matching (Pellegrino et al., 1991) and visual search paradigms (Marković and Gvozdenovi, 2001). On the other hand, Mavrides and Brown (1969) explicitly manipulated the redundancy (i.e., nonrandomness; Donderi, 2006) in the shape of different polygons, finding that less redundant figures (i.e., more complex shapes) were easier to remember. Likewise, other authors showed that simpler shapes are harder to discriminate (Evans, 1967; De-Wit et al., 2017). A possible explanation comes from Donderi (2006), who claimed that simplicity reduces information content, making figures more similar, thus causing difficulties in recognition. Here, we operationalized shape complexity as the number of target lines related to the number of elements composing the

figure (Marković and Gvozdenovi, 2001; Donderi, 2006). Our findings reveal a U-shaped relationship between target complexity and disembedding performance, indicating that both complex and very simple figures are detected better than shapes with intermediate complexity. Indeed, this evidence could reconcile the contradictory results reported in the literature.

Also, the number of continued lines inversely related to disembedding accuracy is well explained by the good continuation principle, which postulates that elements aligned to one another tend to be integrated into the same perceptual unit (Wertheimer, 1923). The influence of good continuation on perception has been demonstrated in both infants (Quinn and Bhatt, 2005) and adults (Prinzmetal and Banks, 1977; Pelli et al., 2009). In the L-EFT, good continuation relates to the number of lines starting from the target shape and continuing into the context, thus influencing the effectiveness of targets' embedding (De-Wit et al., 2017).

Our study explored the influence of demographic factors on disembedding performance and found that younger individuals score higher than elders. A large body of research supports the existence of a negative correlation between age and performance at different versions of the EFT (Lee and Pollack, 1978; Panek et al., 1980; Wiker et al., 2009; Chan and Yan, 2018). Indeed, due to the physiological deterioration of top-down processing with age (e.g., *working memory, speed of processing, inhibitory control*; Park and Reuter-Lorenz, 2009), individuals tend to rely more on external cues, and their ability to filter out environmental information unrelated to the task progressively decreases (Chan and Yan, 2018). Furthermore, it is well documented that a general decline occurs for tasks that require high-level cognitive processing and mental manipulation (Park and Reuter-Lorenz, 2009; Techentin et al., 2014), such as spatial tasks (De Bruin et al., 2016).

The comparison between the performance of men and women in spatial tasks provided mixed evidence across the literature (Maccoby and Jacklin, 1974; Linn and Petersen, 1985; Voyer et al.,

1995; Baron-Cohen, 2002; Hyde, 2005; Andreano and Cahill, 2009; Borella et al., 2014; Miller and Halpern, 2014). For instance, Linn and Petersen (1985) found sex differences in *spatial perception* and *mental rotation experiments*, but not in *spatial visualization tasks*, such as the EFT. Conversely, in line with studies in children (Nebot, 1988; Auyeung et al., 2012), our results reveal significant differences in disembedding abilities between the two sexes, with females performing worse than males in a spatial visualization task. Also, the gap in performance at detecting target shapes is particularly heightened for more complex embedding contexts (i.e., when the number of continued lines is intermediate or maximum). When investigating the interaction between sex and shape properties, our findings also indicate a male advantage in detecting geometrical targets characterized by symmetry and closure. As far as symmetry is concerned, studies highlighted that both sexes show a preference for symmetrical faces and bodies (Wade, 2010) and that males prefer symmetrical abstract figures (Shepherd and Bar, 2011). The males advantage in processing symmetrical geometric shapes found in our data, may be consistent with the ‘*processing fluency hypothesis*’ (Reber et al., 2004; Winkielman et al., 2006; Cárdenas and Harris, 2006), which suggests a positive link between aesthetic pleasantness and processing easiness.

Since the earlier formulation of FDI, Witkin referred to the educational context as one of the most promising fields for applying his theoretical work (Witkin, 1976). Over the years, several studies highlighted the positive correlation between field independence and students’ achievement on various school subjects (Roszkowski and Snelbecker, 1987; Tinajero and Páramo, 1997; Nicolaou and Xistouri, 2011). In particular, the analytical approach of field-independent people seems more suited to the academic environment, thus promoting learning performance (Kagan and Zahn, 1975; Shade, 1983; Clark and Roof, 1988). Indeed, according to Witkin and Goodenough (1981), field-independent individuals find it easier to organize novel and unstructured information. According

to Guisande and colleagues (2007), field-independent people are also more efficient in inhibiting goal-irrelevant information and maintaining attention to relevant stimuli. Other researchers highlighted the relationship between EFT performance and a wide range of cognitive abilities (e.g., working memory, intelligence; Rittschof, 2010; Evans et al., 2013; Danti et al., 2018), which are known to be related to educational outcomes (Lövdén et al., 2020; Strenze, 2007). Of note, Tinajero and Páramo (1997) observed a significant association between academic achievement and field independence, specifically assessed through EFT. In line with these findings, our results show that individuals holding a university degree scored higher at the L-EFT than those with a high school diploma. Specifically, we found that college graduates were better at recognizing open and asymmetrical targets and shapes embedded in complex contexts. We speculate that, as is the case of other non-verbal abilities (Lövdén et al., 2020; Strenze, 2007), long-lasting education enhances EFT performance, by sharpening cognitive strategies and test-taking skills.

The current study presents some limitations that could be addressed in future works. Firstly, our sample is composed of bank employees. Employment is one of the main components of the socio-economic status (SES), which is associated with performance at several cognitive tests (Noble et al., 2005; Farah et al., 2006; Duncan and Mangnuson, 2012). Thus, occupation and training may have exerted an effect on the association between disembedding performance and sex, age and education level reported in the current study. However, it is worth mentioning that our participants have been recruited throughout Italy (i.e., 97 out of the 107 Italian districts), encompassing a variety of socio-cultural backgrounds. Such heterogeneity may have compensated the similarity in participants' occupation and training.

Secondly, we measured participants' performance in terms of the proportion of correct answers (i.e., accuracy), without taking into account response time. Previous studies collected and analyzed

both measures as they are similarly influenced by task difficulty in perceptual experiments (Palmer et al., 2005). In fact, using the L-EFT, De Wit and colleagues reported no substantial differences between results based on accuracy and those obtained from the analysis of reaction times (De Wit et al., 2017). Future studies could verify whether the relationship between demographics and disembedding abilities replicates when reaction times are measured.

Lastly, it should be noted that our analyses were limited to perceptual features originally included in the L-EFT (i.e., *vertical symmetry, closure, number of target lines, number of continued lines*). This set of features is not exhaustive and further studies are needed to explore the influence of other shape features, such as horizontal symmetry, diagonal symmetry or curvature of boundaries (Chambers et al., 2018), on disembedding performance.

In summary, our findings highlight that target asymmetry and good continuation with the embedding context increase task difficulty in a spatial visualization test. Also, target complexity demonstrates a U-shaped relationship with disembedding performance, which may reconcile conflicting evidence found in the literature. Further, results unveil differences between the sexes for spatial visualization tasks that have not been reported so far in adult individuals and corroborate the association between age, educational attainment, and disembedding performance.

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